

3.1.2. EXPERIMENTAL METHODS

Extensive aerosol properties monitored by CMDL include condensation nucleus (CN) concentration, aerosol optical depth (δ), and components of the aerosol extinction coefficient at one or more wavelengths, i.e., total scattering (σ_{sp}), backward hemispheric scattering (σ_{bsp}), and absorption (σ_{ap}). At the regional sites, size-resolved impactor and filter samples (submicrometer and supermicrometer size fractions) are obtained for gravimetric and chemical (ion chromatograph) analyses. All size-selective sampling, as well as the measurements of the components of the aerosol extinction coefficient at the regional stations, is performed at a low, controlled relative humidity (<40%) to eliminate confounding effects due to changes in ambient relative humidity. Data from the continuous sensors are screened to eliminate contamination from local pollution sources. At the regional stations, the screening algorithms use measured wind speed, direction, and total particle number concentration in real time to prevent contamination of the chemical samples. At the baseline stations, algorithms use measured wind speed and direction to exclude data that are likely to have been locally contaminated.

Prior to 1995, data from the baseline stations were manually edited to remove spikes from local contamination. Since 1995, an automatic editing algorithm has been applied to the baseline data in addition to manual editing of local contamination spikes. For the baseline stations, Barrow, Alaska (BRW), Mauna Loa, Hawaii (MLO), American Samoa (SMO), and South Pole, Antarctica (SPO), as well as for Sable Island (WSA), data are automatically removed when the wind direction is from local sources of pollution (such as generators and buildings) as well as when the wind speed is less than a threshold value ($0.5\text{--}1\text{ m s}^{-1}$). In addition, at MLO data for upslope conditions (1800–1000 UTC) are excluded because the airmasses do not represent “background” free tropospheric air for this case. A summary of the data-editing criteria for each station is presented in Table 3.1.

Integrating nephelometers are used to determine the light scattering coefficient of the aerosol. These instruments illuminate a fixed sample volume from the side and observe the amount of light that is scattered by particles and gas molecules in the direction of a photomultiplier tube. The instrument integrates over scattering angles of $7^\circ\text{--}170^\circ$. Depending on the station, measurements are performed at three or four wavelengths in the visible and near-infrared. Newer instruments allow determination of the hemispheric backscattering coefficient by use of a shutter to prevent illumination of the portion of the instrument that yields scattering angles less than 90° . A particle filter is inserted periodically into the sample stream to measure the light scattered by gas molecules, which is subtracted from the total scattered signal to determine the contribution from the

TABLE 3.1. Data-Editing Summary for NOAA Baseline and Regional Stations

Station	Editing	Clean Sector
South Pole	a, b, c	$0^\circ < \text{WD} < 110^\circ$, $330^\circ < \text{WD} < 360^\circ$
Samoa	a, b, c	$0^\circ < \text{WD} < 165^\circ$, $285^\circ < \text{WD} < 360^\circ$
Mauna Loa	a, b, c, d	$90^\circ < \text{WD} < 270^\circ$
Barrow	a, b, c	$0^\circ < \text{WD} < 130^\circ$
Sable Island	a, b, c	$0^\circ < \text{WD} < 35^\circ$, $85^\circ < \text{WD} < 360^\circ$
Southern Great Plains	a	
Bondville	a	

a: Manual removal of local contamination spikes.
b: Automatic removal of data not in clean sector.
c: Automatic removal of data for low wind speeds.
d: Removal of data for upslope wind conditions.
WD: Wind direction.

particles alone. To calibrate the instruments the sample volume is filled with CO_2 gas, which has a known scattering coefficient.

The aerosol light absorption coefficient is determined with a continuous light absorption photometer. This instrument continuously measures the amount of light transmitted through a quartz filter while particles are deposited on the filter. The rate of decrease of trans-missivity, divided by the sample flow rate, is directly proportional to the light absorption coefficient of the particles. Newer instruments (particle soot absorption photometers (PSAPs), Radiance Research, Seattle, Washington) are calibrated in terms of the difference of light extinction and scattering in a long-path extinction cell, for laboratory test aerosols. Older instruments at the baseline stations (aethalometers, Magee Scientific, Berkeley, California) were calibrated by the manufacturer in terms of the equivalent amount of black carbon (BC) from which the light absorption coefficient is calculated, assuming a mass absorption efficiency of the calibration aerosols of $10\text{ m}^2\text{ g}^{-1}$.

Particle number concentration is determined with a CN counter that exposes the particles to a high supersaturation of butanol vapor. This causes the particles to grow to a size where they can be optically detected and counted. The instruments in use have lower particle-size detection limits of 10–20 nm diameter.

Summaries of the extensive measurements obtained at each site are given in Tables 3.2 and 3.3. Table 3.4 lists the intensive aerosol properties that can be determined from the directly measured extensive properties. These properties are used in chemical transport models to determine the radiative effects of the aerosol concentrations calculated by the models. Inversely, these properties are used in algorithms to interpret satellite remote-sensing data to determine aerosol amounts based on measurements of the radiative effects of the aerosol.

TABLE 3.2. CMDL Baseline Aerosol Monitoring Stations (Status as of December 2001)

Category	Baseline Arctic	Baseline Free Troposphere	Baseline Marine	Baseline Antarctic
Location	Point Barrow	Mauna Loa	American Samoa	South Pole
Designator	BRW	MLO	SMO	SPO
Latitude	71.323°N	19.539°N	14.232°S	89.997°S
Longitude	156.609°W	155.578°W	170.563°W	102.0°E
Elevation (m)	8	3397	77	2838
Responsible institute	CMDL	CMDL	CMDL	CMDL
Status	Operational, 1976; major upgrade, 1997	Operational, 1974; major upgrade, 2000	Operational, 1977	Operational, 1974
Sample RH	RH < 40%	RH < 40%	Uncontrolled	Uncontrolled
Sample size fractions	D < 1 µm, D < 10 µm	D < 1 µm, D < 10 µm	Uncontrolled	Uncontrolled
Optical measurements	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$, $\delta(6\lambda)$	None	$\sigma_{sp}(4\lambda)$
Microphysical measurements	CN concentration	CN concentration	CN concentration	CN concentration
Chemical measurements	Major ions, mass	None	None	None

TABLE 3.3. CMDL Regional Aerosol Monitoring Sites (Status as of December 2001)

Category	Perturbed Marine	Perturbed Continental	Perturbed Continental
Location	Sable Island, Nova Scotia, Canada	Bondville, Illinois	Lamont, Oklahoma
Designator	WSA	BND	SGP
Latitude	43.933°N	40.053°N	36.605°N
Longitude	60.007°W	88.372°W	97.489°W
Elevation (m)	5	230	315
Responsible institute	CMDL	CMDL	CMDL
Collaborating institute(s)	AES Canada, NOAA/PMEL	University of Illinois, Illinois State Water Survey	DOE/ARM
Status	Operational, August 1992; inactive, April 2000	Operational, July 1994	Operational, July 1996; chemistry added, February 2000
Sample RH	RH < 40%	RH < 40%	RH < 40%
Sample size fractions	D < 1 µm, D < 10 µm	D < 1 µm, D < 10 µm	D < 1 µm, D < 10 µm
Optical measurements	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$, $\delta(7\lambda)$
Microphysical measurements	CN concentration	CN concentration	CN, $n(D)$ concentration
Chemical measurements	Major ions, mass	Major ions, mass	Major ions, mass

AES, Atmospheric Environment Service; PMEL, Pacific Marine Environment Laboratory; DOE/ARM, Department of Energy/Atmospheric Radiation Measurement.

TABLE 3.4. Intensive Aerosol Properties Derived from the CMDL Network

Properties	Description
\tilde{a}	The Ångström exponent, defined by the power-law $\sigma_{sp} \propto \lambda^{-\tilde{a}}$, describes the wavelength-dependence of scattered light. In the figures, \tilde{a} is calculated from measurements at 550- and 700-nm wavelengths. Situations where the scattering is dominated by submicrometer particles typically have values around 2, whereas when the scattering is dominated by particles larger than a few micrometers in diameter, values are close to 0.
ω_0	The aerosol single-scattering albedo, defined as $\sigma_{sp}/(\sigma_{ap} + \sigma_{sp})$, describes the relative contributions of scattering and absorption to the total light extinction. Purely scattering aerosols (e.g., sulfuric acid) have values of 1, whereas very strong absorbers (e.g., elemental carbon) have values around 0.3.
g, b	Radiative transfer models commonly require one of two integral properties of the angular distribution of scattered light (phase function): the asymmetry factor g or the hemispheric backscatter fraction b . The asymmetry factor is the cosine-weighted average of the phase function, ranging from a value of -1 for entirely backscattered light to +1 for entirely forward-scattered light. The hemispheric backscatter fraction b is defined as σ_{bsp}/σ_{sp} .
$f(RH)$	The hygroscopic growth factor, defined as $\sigma_{sp}(RH = 85)/\sigma_{sp}(RH = 40)$, describes the humidity dependence of scattering on relative humidity (RH).
α_i	The mass scattering efficiency for species i , defined as the slope of the linear regression line relating σ_{sp} and the mass concentration of the chemical species. It is used in chemical transport models to evaluate the radiative effects of each chemical species predicted by the model. This parameter has typical units of $m^2 g^{-1}$.